"project(s) that global warming will lead to rapid and severe changes in forests of the Great Lakes States, with some areas suffering major die-backs during the first decades of the twenty-first century and some becoming deforested and unable to support trees by the end of that century." Botkin goes on to argue that the natural state of forests is, in fact, one of change and that we err in "believing that the natural condition is one of uniformity and constancy." As we discuss the options and opportunities below, we have to wonder how much the possibilities are amplified or constrained by the issues raised in this paragraph.

I don't want to devote much time here to a discussion of tropical forests except to note that the current annual clearing of tropical forests has been estimated to exceed the area of the state of Tennessee (e.g., Houghton et al. 1987; Myers 1990). The contribution to global CO_2 emissions is probably on the order of 25% of the total. With an integrated global economy, a well-mixed atmosphere, and one global pool of genetic material, we in the U.S. are immune from neither damage nor responsibility for what is happening in developing tropical nations. The area of U.S. forests decreased by 21 million hectares between 1953 and 1987 with loss of an additional 7 million hectares anticipated by 2010 (U.S. Congress 1991).

To illustrate the magnitude of the problem of offsetting fossil fuel related CO_2 emissions, consider the possibility of offsetting all 6 billion tons of carbon emissions with new forest. If we could establish new, fast-growing tree plantations on land that did not previously contain trees, and achieve a productivity of about 30 cubic meters equivalent in total biomass per hectare per year (i.e. a carbon uptake of 7.5 kg C per hectare per year), it would require 800 million hectares to accomplish a full offset. This is slightly smaller than the land area of Brazil. To offset emissions from a single coal-fired power plant operating at 38% thermal efficiency and with a capacity factor of 70% would require about 200 hectares of these plantations per megawatt of capacity. These rough calculations do not make allowance for the energy required to establish and maintain the plantation and they do not suggest what happens when the trees begin to mature and the growth rate drops off. They suggest that planting trees cannot solve the whole problem or even provide a permanent offset for a single fossil-fuel power plant. Trees could, however, provide a way to slow the growth of atmospheric CO_2 while we endeavor to either develop a more friendly energy system or establish a better understanding of the risks of climate change.

To contemplate tree-planting a little more broadly, consider Figure 2. The figure shows cumulative net emissions of CO_2 from a power plant as a function of time and suggests 4 scenarios. In scenario A, the current path, fossil fuels are being burned and there is a continuing increase in the cumulative amount of CO_2 discharged. In scenario B we envision that new forest is established so that growth of the forest is initially able to sequester an amount of carbon equivalent to that discharged by the power plant. As the forest matures, however, the rate of carbon uptake decreases until there is no net carbon uptake. Curve B then becomes parallel to curve A but offset from it by a quantity, a-b in the figure, equal to the amount of carbon stored in the mature forest. In scenario C, there is envisioned to be no fossil fuel burning and the power plant is fueled instead by harvesting from a mature forest. As mature forest is harvested, it is replaced by plantation forest which continues to provide fuel for the power plant. In the early stages, net CO_2 emissions closely track those from the coal-fired plant, but ultimately the rate of net emissions falls to zero as the plantation achieves a steady state of standing biomass. The carbon shown as c-o in the figure represents the difference in standing crop between the mature forest and the plantation forest. In scenario D, we envision that when construction of the power plant is initiated, there is simultaneous establishment of a plantation forest where forest did not previously exist. This plantation forest then provides fuel